4. MONITORED GEOLOGIC REPOSITORY DISPOSAL SYSTEM

The two essential components of the waste disposal system consist of the monitored geologic repository and robust disposal containers. The disposal containers provide containment of the nuclear wastes for at least 1,000 years, while the repository host rocks ensure that radionuclides released from the wastes do not constitute an unacceptable risk to public health and safety or to the environment, in accordance with standards that are to be developed by the Environmental Protection Agency. The disposal system is to operate under a license issued by the Nuclear Regulatory Commission pursuant to 10 CFR Part 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories* (or to new regulations specific toYucca Mountain). A brief description of the disposal container and repository is provided in this section. In addition, a brief description of the repository concept of operations is also provided.

Receipt of waste at the repository is scheduled to begin in 2010 and to continue at the rates shown in Table 8. Although receipt and emplacement rates are assumed to be the same, the actual emplacement rate is a function of the types and sizes of casks and canisters received. Lag storage may be provided at the repository to manage the movement of waste before emplacement and to compensate for any differences between receipt and emplacement rates.

Table 8. Waste Receipt Rates at the First Repository
(In MTHM or Equivalent Per Year)

Year	Commercial Spent Fuel[a]	High-Level Waste[b] and DOE Spent Fuel[c]
2010	400	TBD[d]
2011	600	TBD
2012	1,200	TBD
2013	2,000	TBD
2014	3,000	TBD
2015-2031	3,000	400 TBD
2032	3,000	200 TBD
2033	1,800	0 TBD
Total	63,000	7,000

[a]May include some mixed oxide spent fuel
[b]May include some immobilized plutonium
[c]Including Naval spent fuel
[d]To be determined; (maximum rate of 400 MTHM or equivalent per year expected)

The above receipt rates will allow for emplacement of only a portion of the Nation's projected total nuclear waste inventory, consistent with a constraint imposed by the Nuclear Waste Policy Act. Section 5 will focus on the receipt rates for a repository designed to emplace all of the Nation's projected nuclear waste inventory.

4.1 CONCEPTUAL DISPOSAL CONTAINER DESIGN

Current efforts are focussed on disposal container designs for canistered spent fuel, uncanistered spent fuel, high-level waste, high level-waste co-disposed with DOE spent fuel, and immobilized plutonium canistered with high-level waste. Once the disposal container is loaded and sealed, it is referred to as a waste package.

Table 9 provides a summary of conceptual design characteristics for disposal containers for uncanistered commercial spent fuel. These disposal containers will be designed to hold as much spent fuel as possible without exceeding the physical and thermal load limits placed on the containers. The disposal container for high-level waste co-disposed with DOE spent fuel will accommodate five waste glass canisters and up to nine assemblies of certain types of DOE spent fuel. To ensure substantially complete containment of the wastes in the repository, the disposal containers will be designed to the regulatory requirement of preventing less than one percent of the containers from breaching for at least 1,000 years.

Table 9. Conceptual Disposal Container Characteristics

Waste Container Type	**Outer Diameter m (ft)**	**Outer Length m (ft)**	**Outer Barrier Thickness m (ft)**	**Inner Barrier Thickness m (ft)**	**Tare Mass kg (lb)**	**Loaded Mass kg (lb)**
21 PWR	1.66 (5.45)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	35,000 (77,200)	52,000 (114,700)
12 PWR	1.32 (4.33)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	25,000 (55,100)	35,000 (77,200)
12 PWR[a]	1.35 (4.43)	5.87 (19.26)	0.10 (0.33)	0.02 (0.07)	29,000 (63,900)	39,000 (86,000)
44 BWR	1.60 (5.25)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	33,000 (72,800)	47,000 (103,600)
24 BWR	1.34 (4.40)	5.34 (17.52)	0.10 (0.33)	0.02 (0.07)	28,000 (61,700)	36,000 (79,400)

[a] These disposal containers are slightly larger to accommodate the longer South Texas fuel assemblies

Each disposal container, whose design is based on a defense-in-depth philosophy of using multiple barriers, consists of a cylindrical inner barrier made of Alloy C-22 (a nickel-based alloy) and a cylindrical outer barrier made of ASTM A 516 Grade 55 or 70 carbon steel. Two different barrier materials will support the design approach to have different failure mechanisms to protect against the release of radioactive materials. The outer barrier is a corrosion-allowance material that provides mechanical strength early in the life of the container as well as protects the inner barrier by limiting corrosion to a slow predictable rate. The inner barrier is a corrosion-resistant material that will have a very long life. The functions of the disposal container are to provide a waste containment barrier, act as a structural member to protect the waste from mishandling or falling rock damage, and assist in conducting heat away from the waste. The waste is sealed with an inner barrier lid and an outer barrier lid. The disposal container for uncanistered spent fuel includes a basket for holding the fuel assemblies, which also provides the capability for additional criticality control, if required.

Because of weight and handling limitations, the disposal containers are not designed to provide shielding against radiation from the contained waste; consequently, workers will need to be protected by other aspects of the repository design. These include reinforced concrete walls in the waste handling building, remote handling and robotics, the waste package transporter, and the emplacement drift walls.

4.2 CONCEPTUAL REPOSITORY DESCRIPTION

If approved by the President and Congress, and licensed by the Nuclear Regulatory Commission, the repository will be developed at the Yucca Mountain site, about 160 kilometers (100 miles) northwest of Las Vegas in Nevada. The site is currently undergoing characterization to determine its suitability for hosting the repository. Site characterization activities include surface- and subsurface-based testing at Yucca Mountain. Data collected to date have been used to support the viability assessment of the Yucca Mountain site. Additional data will be collected to support site suitability recommendation to the President and license application to the Nuclear Regulatory Commission.

Although the statutory capacity of the repository is 70,000 MTHM or equivalent of spent fuel and high-level waste, the repository will be physically capable of accommodating a larger capacity. A single repository that is capable of emplacing all of the Nation’s projected nuclear waste inventory is a cost-effective alternative to a second repository, the need for which is to be recommended by the Secretary of Energy to the President between January 1, 2007 and January 1, 2010. This alternative will be examined in Section 5.

The conceptual repository design consists of surface and subsurface facilities, which constitute the geologic repository operations area, as defined in 10 CFR Part 60.2.

4.2.1 SURFACE FACILITIES

The nuclear wastes that are destined for disposal in the repository will be received and packaged for emplacement in a 32-hectare (80-acre) area located at the northern entrance to the potential repository (the North Portal Operations Area). The operations involving radioactive materials will be conducted in a Radiologically Controlled Area. Support operations will be accomplished in the Balance of Plant Area.

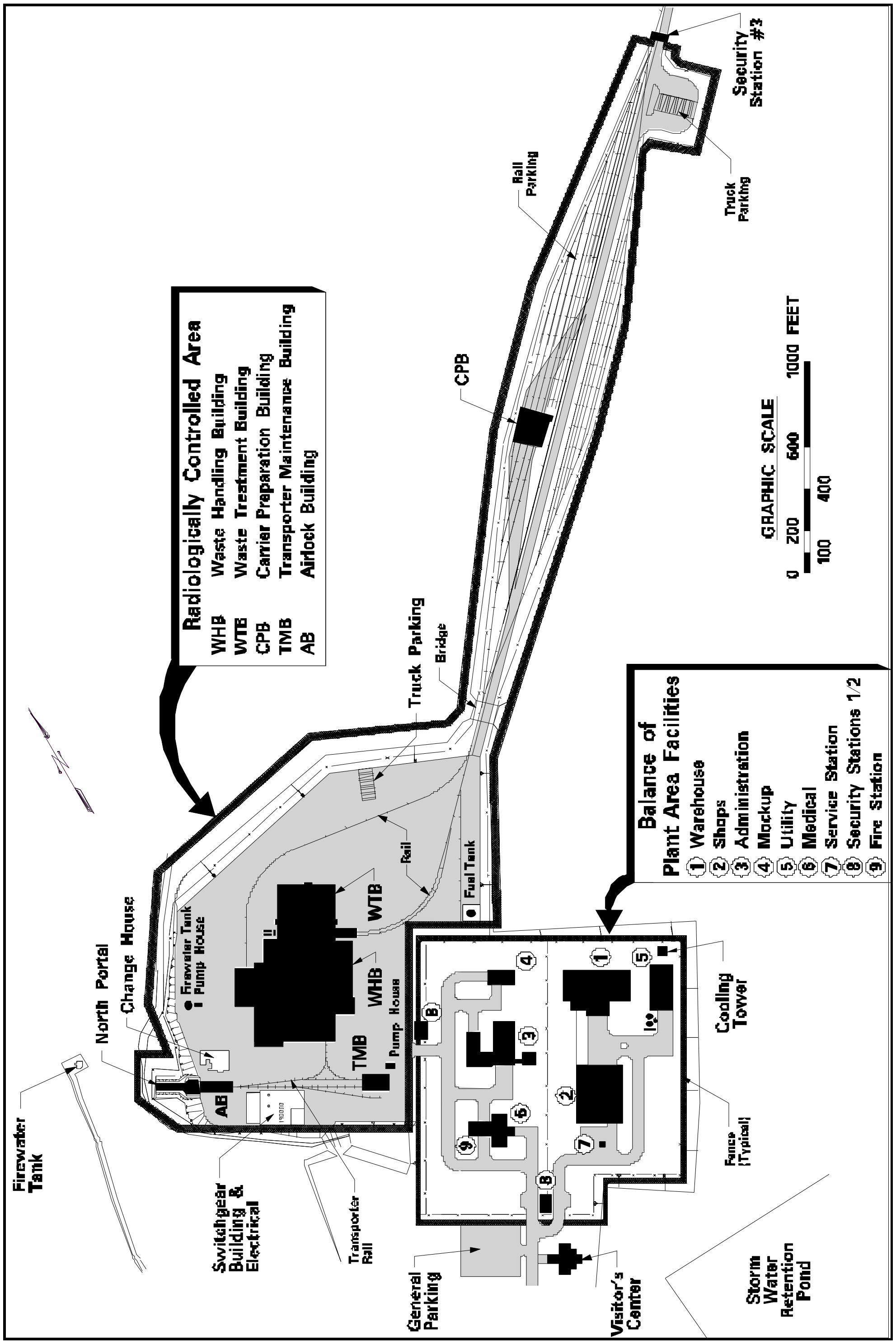

Figure 1. Conceptual Surface Facility Layout of the North Portal Operations Area

The Radiologically Controlled Area includes the Carrier Preparation Building, where shipping casks are prepared for removal from rail or truck carriers. Spent fuel assemblies and disposable waste canisters will be packaged for disposal in the Waste Handling Building Within the Waste Handling Building, there are five processing lines -- three wet lines and two that are dry. The wet processing lines are used to extract spent fuel assemblies from transportation casks or non-disposable canisters and place them in disposal containers. The dry processing lines only handle high-level waste or spent
fuel in disposable canisters. The Waste Handling Building also includes welding stations for sealing the disposal containers, and staging areas for loaded disposal containers waiting to be sealed or for waste packages awaiting transfer to the subsurface emplacement areas. The Radiologically Controlled Area also includes a Waste Treatment Building for the treatment of low-level waste; a Transporter Maintenance Building for servicing and repairing vehicles which are used for transporting and emplacing waste packages in the repository; and an Airlock Building at the entrance to the North Portal.

The Balance of Plant Area includes security stations, an administrative building, a fire/medical center, a warehouse, central maintenance shops, a motor pool and facility service station, a mock-up building for training, a utility building, and a visitors' center. The conceptual surface facility layout for the North Portal Operations Area is shown in Figure 1.

Three other operations areas are included in the surface facilities. The South Portal Operations Area, covering about 12.1 hectares (30 acres) adjacent to the southern entrance to the repository, provides systems and equipment to support the development of subsurface facilities. The surface facility here includes a concrete plant for fabricating and curing precast components and supplying concrete for in-place casting, and basic structures for personnel support, maintenance, warehousing, material staging, security, and transportation. The remaining two areas, each of minimal acreage, are the Emplacement Ventilation Shaft Operations Area, and the Development Ventilation Shaft Operations Area. These two areas have systems and equipment that provide ventilation to support development and emplacement operations underground.

4.2.2 SUBSURFACE FACILITIES

The waste emplacement horizon in the repository will be located in the Topopah Spring Member, a welded tuff unit of the Paintbrush Tuff. At Yucca Mountain the Topopah Spring Member has a maximum thickness of approximately 350 meters (1,150 feet) and dips about 6 degrees to the east. Potentially usable emplacement areas are delineated by major faults. These potentially usable areas, which total about 3,700 hectares (9,150 acres), include a primary area and expansion areas.

The primary area consists of an emplacement block bounded on the east by the Ghost Dance Fault, on the west by the Solitario Canyon Fault, and on the south by the thinning of the Topopah Spring Member in the repository horizon. This block provides about 300 hectares (740 acres) for emplacing 70,000 MTHM or equivalent of waste at a mass loading of 210 MTHM per hectare (85 MTHM per acre). It is located at least 200 meters (660 feet) below the surface and at least 100 meters (330 feet)

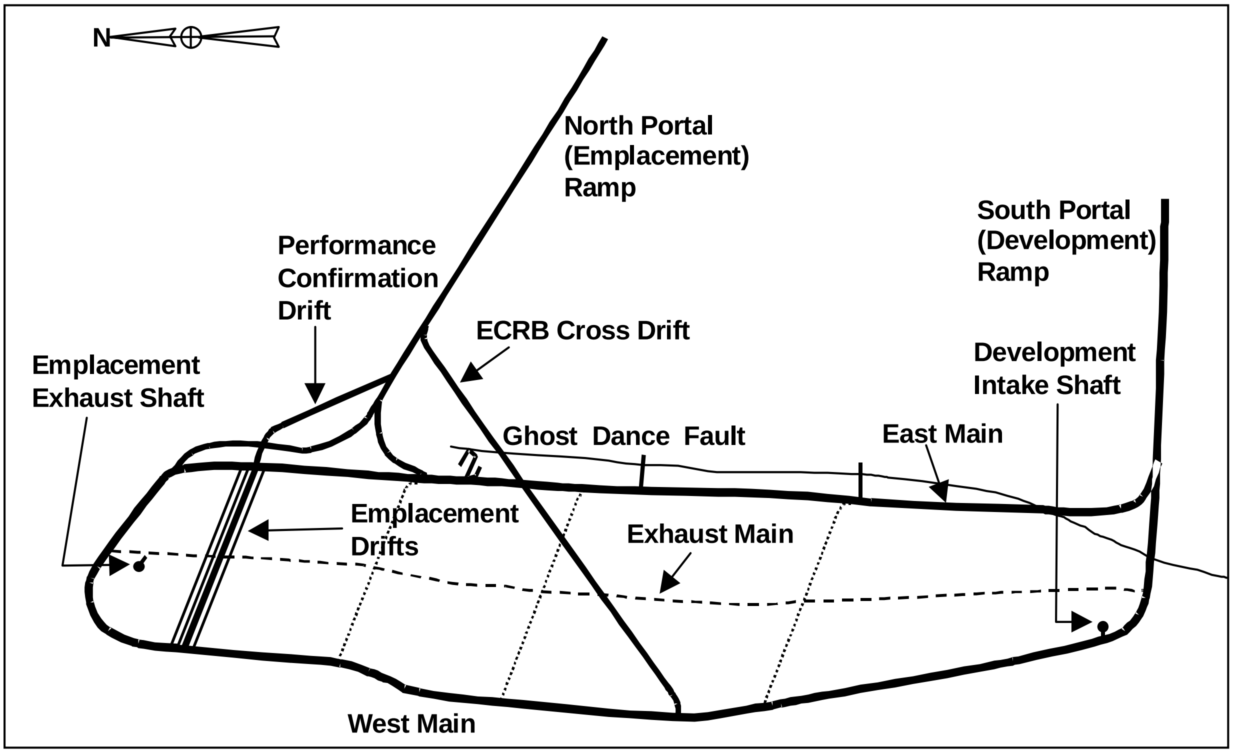

Figure 2. Conceptual Subsurface Facility Layout of the Repository

above the regional water table. Significant expansion areas are potentially available both to the north and south of the planned emplacement area. Up to 470 hectares (1,150 acres) are potentially available but additional characterization activities would be required to validate much of this expansion area.

The conceptual layout of the subsurface facilities, shown in Figure 2, consists of two ventilation shafts, two ramps, two main drifts, about 105 waste emplacement drifts, a central exhaust drift, and five performance confirmation drifts. As a contingency the primary emplacement area contains space for an additional 15 drifts, which will be used if unstable ground conditions are encountered within the intended emplacement areas or if additional space is needed for waste packages with exceptionally high thermal loads. When completed, the layout will contain about 150 kilometers (93 miles) of drifts.

Five of the emplacement drifts will remain empty during emplacement operations. These drifts will be at locations that will divide the emplacement block into areas of similar size. Three of the empty drifts will be designated as cross-block drifts and will be used to facilitate ventilation, emergency egress, and performance confirmation monitoring. The remaining two empty drifts will serve as standby drifts for relocating waste packages, if necessary.

The ramps and main drifts are 7.6 meters (25 feet) in diameter and are used for waste transport, ventilation, service utilities and personnel access. The North and South Portal Ramps and the main drifts have grades of less than 3 percent to ensure the safe use of heavy rail transport to the emplacement horizon.

The central exhaust drift, located about 10 meters (33 feet) beneath the emplacement block, has a diameter of 7.6 meters (25 feet), and provides exhaust ventilation for the emplacement drifts. It is connected to each of the emplacement drifts by raises (small shafts vertically bored) that are 2.0 meters (6.6 feet) in diameter.

The five performance confirmation drifts, each with a diameter of 5.5 meters (18.2 feet), are located about 15 meters (49 feet) above the emplacement block. Boreholes will be drilled from these drifts to approach the rock mass near the emplacement drifts, and instruments will be installed in the boreholes to monitor conditions in the host rock. Other instruments will be installed in the performance confirmation drifts that will monitor air temperature and humidity in the drifts.

Emplacement drifts are 5.5 meters (18.2 feet) in diameter, and are spaced at 28 meters (92 feet) between the centers of each drift. They may have lengths of approximately 900 meters (2,960 feet) to 1,200 meters (3,950 feet). Each emplacement drift has a set of doors at both ends of the drift to control access. Each set of doors has ventilation regulators (louvers) to control the flow of air through the emplacement drift. These doors are remotely controlled from a safe location within the main drift. Approximately 5 percent of the total number of emplacement drifts will be developed prior to the start of emplacement operations. Development of the remaining 95 percent of the emplacement drifts will be performed concurrently with waste emplacement during the repository operations phase, using two separate, independent ventilation systems. One system will provide ventilation for the excavation operations required for drift development, while the other provides ventilation for the waste emplacement operations. Movable temporary walls (isolation air locks) installed in the main drifts at the points that divide the two operations will keep the two ventilation systems separate. As excavation and emplacement operations progress, these walls will be moved to new positions in the main drifts, thus providing access to the newly excavated drifts for waste emplacement.

The ventilation system that supports drift development operations will force air into the drifts by way of surface-located fans at the intake shaft; exhaust air through the South Portal ramp; and maintain air pressure in the development area above that in the emplacement area. The intake shaft is a concrete-lined vertical shaft 6.1 meters (20 feet) in diameter.

The ventilation system that supports waste emplacement operations will pull air through the North Portal ramp into the emplacement area using surface-located fans at the exhaust shaft; exhaust air through the exhaust shaft; maintain air pressure in the emplacement area below that in the excavation area; and contain high efficiency filters that will activate in the event subsurface radionuclide release is detected. The exhaust shaft is a concrete-lined vertical shaft 6.1 meters (20 feet) in diameter.

The ventilation system maintains the temperature at 27ºC (80ºF) in areas where personnel are working. Personnel are not allowed in the emplacement drifts during emplacement operations. These emplacement drifts are ventilated during waste emplacement to ensure that the drift temperature does not exceed 50ºC (122ºF).

The design of the subsurface facilities accommodates a range of thermal loadings in order not to preclude alternative waste emplacement options that may be shown to be safe by test data obtained after construction is authorized. The conceptual design assumes a thermal loading of between 22.5 watts per square meter (91 kilowatts per acre) and 28.2 watts per square meter (114 kilowatts per acre). This corresponds to a mass loading of between 19.8 kilograms of uranium per square meter (80 MTHM per acre) and 24.7 kilograms of uranium per square meter (100 MTHM per acre). The required thermal loading will be achieved through a combination of strategies (such as drift spacing and waste package spacing within the drifts) that are appropriate for meeting waste package and repository near-field thermal constraints. The wall temperature in each emplacement drift will be less than 200ºC (392ºF).

4.3 REPOSITORY CONCEPT OF OPERATIONS

Each transportation cask arriving at the repository site will pass through a security station and enter the Radiologically Controlled Area near the North Portal where it is inspected by repository personnel for tampering and compared against its documentation. If the cask is off-normal (unacceptable), it is moved to a holding area pending corrective action. If the cask is acceptable, it is moved to a parking area and inspected for radiological contamination. The cask is then disconnected from its off-site transporter and connected to a on-site transporter which moves it to the Carrier Preparation Building. The off-site transporter remains in the Radiologically Controlled Area until an empty cask is ready to be shipped back to a Purchaser site. In the Carrier Preparation Building, personnel barriers and impact limiters are removed from the cask. A radiological survey is performed and the cask is then moved to a wash-down station where road grime is removed from its transport carriage prior to entering the Waste Handling Building.

In the Waste Handling Building, individual fuel assemblies in casks or in non-disposable canisters are unloaded and transferred to appropriate disposal containers, using remote handling equipment. Individual fuel assemblies will be placed into staging racks if there is an insufficient number of assemblies with compatible characteristics to fill a disposal container. Disposable canisters (with spent fuel or high-level waste) are unloaded from their transportation casks and transferred directly into their respective disposal containers or may be staged within a hot cell. A limited amount of lag storage is provided for high-level waste canisters to facilitate co-disposal with DOE spent fuel. During the transfer, the identity of each fuel assembly, canister, and/or cask involved is verified and recorded to provide appropriate material control and accounting, and maintain continuity of knowledge of waste disposition. When loading of each disposal container is completed, it is moved to a welding room where an inner barrier lid is welded by remote control and the integrity of the weld is verified. The outer barrier lid is then welded and the integrity of the weld is verified before the resulting waste package is moved to the staging area to await transport to the subsurface emplacement area. The unloaded transportation cask is decontaminated, if necessary, and prepared for shipment off the site.

Each waste package is prepared for delivery into the emplacement area by decontaminating it, if necessary, and placing it on a transfer rail car. The identity of the waste package and its contents is verified and recorded. A shielded waste package transporter is brought into the staging area and the transfer rail car is pulled into the transporter by a remotely-controlled mechanism. The transporter doors are closed and the waste package is ready to be moved underground for emplacement.

Two locomotives pull the transporter down the North Portal ramp to the waste handling main drift and then to the entry area for the designated emplacement drift. At the emplacement drift the transporter is positioned by remote control in front of the drift using one of the locomotives. The emplacement drift door and the transporter doors are opened by remote control, and the transporter moves the transfer rail car and waste package into the drift. A mobile gantry is then positioned to lift the waste package off the rail car and move it to its assigned support asembly within the drift. The emplacement location of the waste package is recorded. The rail car is retrieved from the drift, the drift door is closed, and the transporter is returned to the surface.

During the period of waste emplacement and lasting until repository closure, a performance confirmation program, established during site characterization, is continued. The purpose of performance confirmation is to confirm the predicted performance of the engineered and natural barrier systems relative to waste containment and isolation. The performance confirmation activities provide data to show that subsurface conditions and changes resulting from construction and waste emplacement operations are within predicted limits. They also verify that the natural and engineered systems and components are functioning as anticipated and intended. This information is to be used in support of an application to the Nuclear Regulatory Commission for a repository license amendment to permanently close the repository.

The repository will be designed to remain open for a period of 100 years from the start of initial waste emplacement. This design concept is expected to provide the flexibility to extend that period to 300 years, if required. The extended service life of 300 years would allow future generations to decide whether it is appropriate to continue to maintain the repository in an open, monitored condition or to close it based upon development of their own criteria and level of certainty regarding ultimate repository performance. The emplaced waste will be retrieved if performance confirmation activities indicate that the repository is unsuitable for disposal and long term isolation of the waste, or if recovery of the waste as a valuable resource is warranted. Retrieval concepts are currently being evaluated, and they will be incorporated in a future revision of this document once they are developed.

Closure of the repository begins after DOE receives a repository license amendment from the Nuclear Regulatory Commission. The process includes closure of the subsurface facilities; dismantling, decontamination and decommissioning of the surface facilities; site reclamation and restoration; and protecting the repository from unauthorized intrusion.

Closure of the subsurface facilities consists of removing all nonpermanent equipment; filling in the main drifts, ramps and shafts; and installing seals in all openings to the surface, including shafts, ramps, and any boreholes that have been drilled to the repository horizon. Backfilling of the emplacement drifts is not currently required, but flexibility is included in the design so that backfilling is not precluded.

The surface facilities are designed to include features that facilitate dismantling, decontamination and decommissioning operations. The Waste Treatment Building supports decontamination and decommissioning activities by providing solid and liquid low-level radioactive waste treatment and packaging for transport to an off-site low-level waste disposal site. Hazardous and mixed wastes, if generated, are collected and packaged for transport to off-site licensed facilities for treatment and disposal.

At the completion of site reclamation and restoration, institutional and physical barriers are established. Detailed records and information on the repository are distributed to local, state and federal agencies for their use in controlling access to the site, thus creating institutional barriers. Physical barriers include fences, warning signs, markers, and monuments.